CONE PENETROMETER

FOR LUNAR SUBSURFACE

SOIL EVALUATION

(NASA-CR-182916) CONE PENETROMETER FOR LUNAR SUBSURFACE SOIL EVALUATION Final Report (Georgia Inst. of Tech.) 40 p

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DAVID MORLAN

FINAL REPORT
DUE: 6/3/85

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PROBLEM STATEMENT: A cone penetrometer is being designed to be used to derive a strength profile of the lunar surface. The instrument will be lowered into a predrilled hole and measurements will be taken at predetermined increments.

BACKGROUND: NASA is sponsoring ME4182 students to do lunar space station research. Equipment for the preparation and inspection of the lunar surface is necessary before the biulding of a space station can be considered.

CONSTRAINTS:

1 - Must operate under extreme lunar temperatures (-135 C - +120 C)

2 - Must operate in a vacuum.

3 - Must be able to withstand cosmic and nuclear radiation.

4 - Must operate at one sixth Earth's gravity.

5 - Instruments and controls must be visible in the presence of dark shadows.

6 - Controls must be operable by men in space suits.

7 - Must fit into a 5.5 inch diameter hole.

8 - Must be self supporting system.

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SPECIFICATIONS:

I. Testing unit

- Dimensions:

  Diameter = 5.45 inches
  Length = 65.00 inches

- Power: Hydraulically

- Materials:

  Steel: Frame, Housing, Cone, Cone shaft, Lock Pads, Hydraulic cylinders

- Cone Angles = 30 , 60

- Max. Penetration Depth = 15 inches

- Shaft Dia. = .750 inches

- Maximum Test Force = 350 lbs.

- Accuracy = .2 Percent

II. CONTROLL UNIT

- Dimensions:

  Height = 73.4 inches
  Length = 36 inches
  Depth = 31 inches

- Powered: Electrically

- Materials:

  Steel: Frame, Legs, Hydraulic Pump.

- Instruments:

  Force Gage
  Current Penetration Depth
  Cone Index
  Test Depth
  Hydraulic Pressure

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INTRODUCTION

A cone penetrometer is an instrument used to provide a uniform method of measuring the penetration resistance of soils. The force required to push a 30 degree cone through the soil is known as the "cone index". The cone index serves only as a means of describing and reporting the soil resistance to penetration, and does not provide specific values of soil properties such as cohesion, angle of friction or coefficient of soil metal friction.

INDUSTRY STANDARDS

THE AMERICAN SOCIETY OF AUTOMOTIVE ENGINEERS recommends the following standards for cone penetration testing. The recommended cone size is .798 inch base diameter with a 30 or 60 degree apex angle. A .625 inch diameter shaft is used to provide good strength. AISI 416 stainless steel, machined to a smooth finish (63 microinches maximum) is recommend as a suitable cone finish. Penetrometer cones should be replaced when the base diameter wear exceeds 3 percent. Non-standard data should be reported with a description of the penetrometer and its method of use. The recommended test speed is 72 inches per minute.

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CONE PENETROMETER FOR LUNAR SUBSUFACE SOIL EVALUATION

EQUIPMENT DISCUSSION

GENERAL

The cone Penetrometer discribed in this section is meant to be used for deriving a subsurface soil Profile on the moon. The basic idea is the test unit is to be lowered down into a Predrilled hole, and tests are to be Preformed at various depths. The test is controlled by a certified oPerator from a control Panel located on the surface (See Fig. 1).

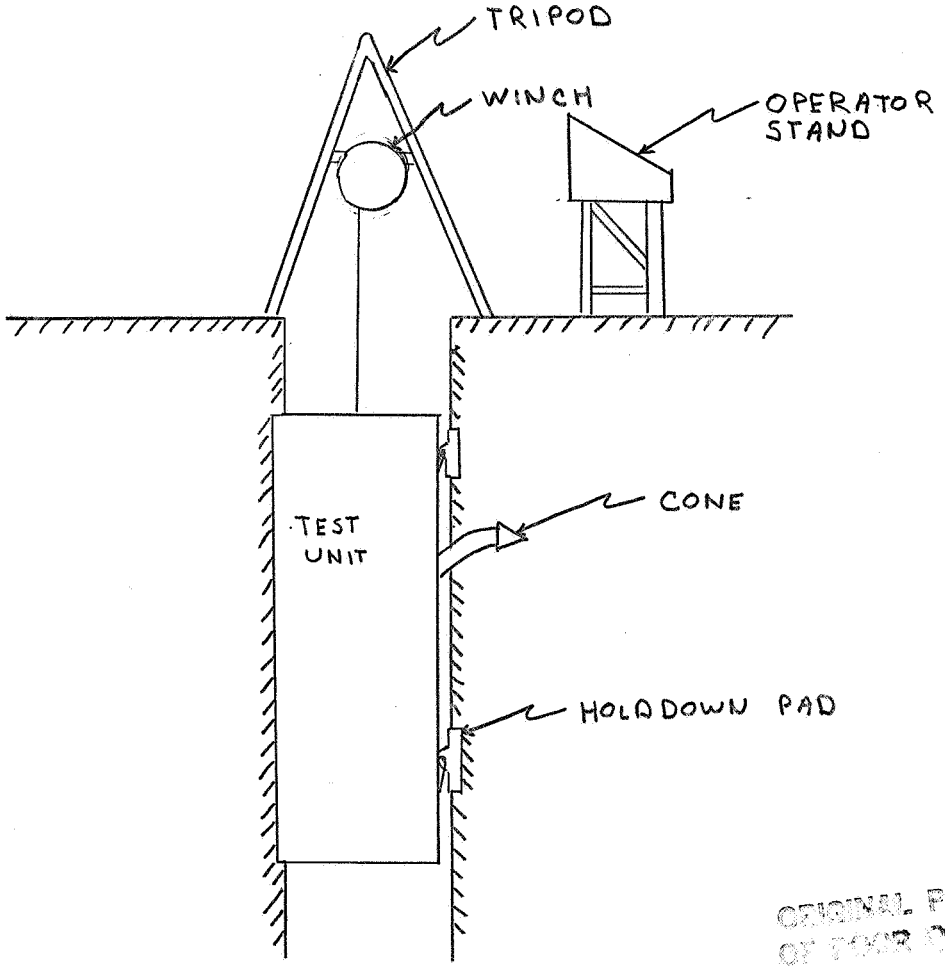

FIG. 1

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CONE PENETROMETER FOR LUNAR SUBSURFACE SOIL EVALUATION

TEST UNIT

The test unit is the major component of the system. The unit's overall dimensions are 5.45 inches in diameter and 65.00 inches long. At the heart of the unit is a frame fabricated from 1/2 inch steel plate. Mounted to the frame are the holddown assembly, the test cylinder, the control sensors, and the hydraulic control components. The test units internal components are protected from damage and contamination by a sheet metal guard which is also mounted to the frame.

The holddown system consists of two separate but identical assembly, one being located at each end of the test unit. The components of the holddown assembly are a hydraulic cylinder, a holddown lever, and a holddown pad. The holddown lever is mounted to the frame at one end with a pin joint. To the other end of the lever by another pin joint is mounted the holddown pad. When the hydraulic cylinder is activated the holddown pad is pushed out against the wall of the hole, this in turn forces the back of the frame against the opposite wall holding the unit firmly in place.

The testing system is comprised of a specially designed curved hydraulic cylinder. The cylinder is

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mounted to the frame at three locations through load cells. The load cells must be capable of measuring both compression and tension, with a high tolerance to shear loading. The curved cylinder has a radius (centerline) of 16.25 inches, with a 1.5 inch bore. The large curvature allows the cylinder to have a 15 inch stroke, which provides adequate penetration depth for accurate results. The working pressure of the cylinder is 200 psi, which provides 350 lbs. of force in the forward stroke (test stroke). This configuration creates a 45 degree entrance angle for the cone which decreases rapidly as the penetration depth increases. This assures that the effects of the surface will not adversily effect the test results.

OPERATOR STAND

The operator stand serves three purposes. First to control all aspects of the units operation, second to provide the operator with information about system status, and third to provide the source of hydraulic power.

From the operator stand the operator can control all aspects of the test procedure. These functions include raising and lowering of the test unit, locking and retracting of the holddown assembly, and running the test itself. The control is provide by a series of rotary and

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push button switches. In addition an oversized main power switch is centrally located on the panel to allow the operator to cut all power (including hydraulic) in the case of an emergency.

The control panel also provides the operator with feedback of system status. Large LED displays allow the operator to monitor system pressures, test and penetration depths, test and holddown force, test speed, and a direct read out of the cone index.

The operator stand also houses an accumulator which provides the hydraulic power. The accumulator has a 231 cu. inch volume which is twice the volume necessary to run one test. The accumulator is charged with nitrogen to 250 psi before it is brought to the test sight. The operator uses a hand pump to fill the accumulator with hydraulic fluid before a test is run.

SUPPORT SYSTEM

The support system is a tripod arrangement used to support the test unit when it is not in the "locked" position. Mounted to the tripod is a small DC winch used to raise and lower the test unit. Also mounted to the tripod is a coil used to feed out and pull in the hydraulic hose. The DC winch is power by several sealed 12 volt

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Batteries.

CONTROL/COMPUTER SYSTEM

All system parameters are monitored and stored by a small computer. The computer monitors various sensors and converts their outputs to voltages so they can be displayed on the control panel. The penetration depth is found from the current output of an optical encoder located by the shaft of the test cylinder. This same optical encoder in conjunction with a clock is also used to determine test speed. The computer controls the test speed to maintain it constant by varying the flow rate of the hydraulic fluid.

The computer receives voltage inputs from the load cells and from these voltages computes the test force. Using the test force and the penetration depth the computer computes and displays the "cone index".

To compute the holddown force the computer monitors the pressure in the holddown cylinder and the angle of the holddown lever. From this information the computer can compute and display the holddown force.

The test depth is monitored by passing the cable used to lower the test unit over a small pulley with a hole in it. Using a LED the number of revolutions of the pulley can be counted and the test depth calculated.

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The computer stores all data in raw form on a cassette tape to be processed later on a larger computer and a printout made for evaluation. The data collected is then compared to data taken on soil with known properties.

HYDRAULIC SYSTEM

The units hydraulic system consists of an accumulator, three double acting cylinders, and various control values.

The accumulator supplies the hydraulic pressure to the system. It is of the non - separated type with nitrogen as the charging fluid. The accumulator has a maximum capacity of 231 cu. inches twice the fluid volume needed to run one test. A hand pump is used to fill the accumulator with fluid before a test is run.

The three cylinders are all of the double acting type. Two are stock items, and the third is specially design for this system. The cylinder all have a working pressure of 200 psi. The cylinders are also rebuilbable.

There are three types of valves used in the hydraulic system, though all are electrically controlled by the computer. First, 4 - way spool valves are used to control the double acting cylinders. A flow control valve is used to allow the computer to maintain a constant test speed.

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Because the Pressure in the accumulator is not constant a Pressure reducing valve is used to maintain the 200 Psi in the cylinder side regardless of the Pressure in the accumulator.

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CONE PENETROMETER FOR LUNAR SUBSUFACE SOIL EVALUATION

EQUIPMENT CALIBRATION

DEVIATION FROM STANDARD

The test system of this unit deviates from standard in two major respects. First, the shaft is slightly oversized .750 inches in diameter instead of the standard .650 inches. Second, the shaft is not straight. The curvature of the test cylinder is necessary to Provide the necessary Penetration depth needed for accurate results.

The curvature of the shaft has been made as large as Possible to mimimize the effect of the curvature.

Because of these differences from standard an extensive Program will have to be undertaken to collect data on known soil. The unit will have to be tested on soil with known Properties and the data tabulated, for comParison when soils with unknown Properties are tested, such as the lunar soil.

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TEST PROCEDURES

The following is a step by step procedure to be followed when running a Penetration test with the Penetrometer described in the Preciding section.

CALIBRATION

1 - Turn on main Power.
2 - Turn raise - lower switch to lower.
3 - Press "start" (under raise - lower)
4 - When the cone is even with the ground Press "stop" (under raise lower switch).
5 - Press "zero" button located at the lower right corner of the test depth display.

LOWER UNIT

1 - Turn raise - lower switch to "lower".
2 - Press "start" (under raise - lower switch).
3 - Watch test depth display.
4 - When desired depth is reached Press "stop".

LOCK UNIT

1 - Turn lock - retract switch to lock.
2 - Press "start" (under lock - retract switch).
3 - Watch holddown force display.
4 - When holddown force reaches 200 lbs. Press "stop".

TEST

1 - Turn test - retract switch to "test"
2 - Press "start" (under test - retract switch).
3 - Test will stop automatically.
4 - Turn test - retract switch to "retract".
5 - Press "start".

UNLOCK UNIT

1 - Turn lock - retract switch to lock.
2 - Press "start" (under lock - unlock switch).
3 - Retraction stop automatically.

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CONE PENETROMETER FOR LUNAR SUBSURFACE SOIL EVALUETION

RAISE UNIT

1 - Turn raise - lower switch to "raise".
2 - Press "start" (under raise - lower switch).
3 - When unit has reached new desired depth press "stop".

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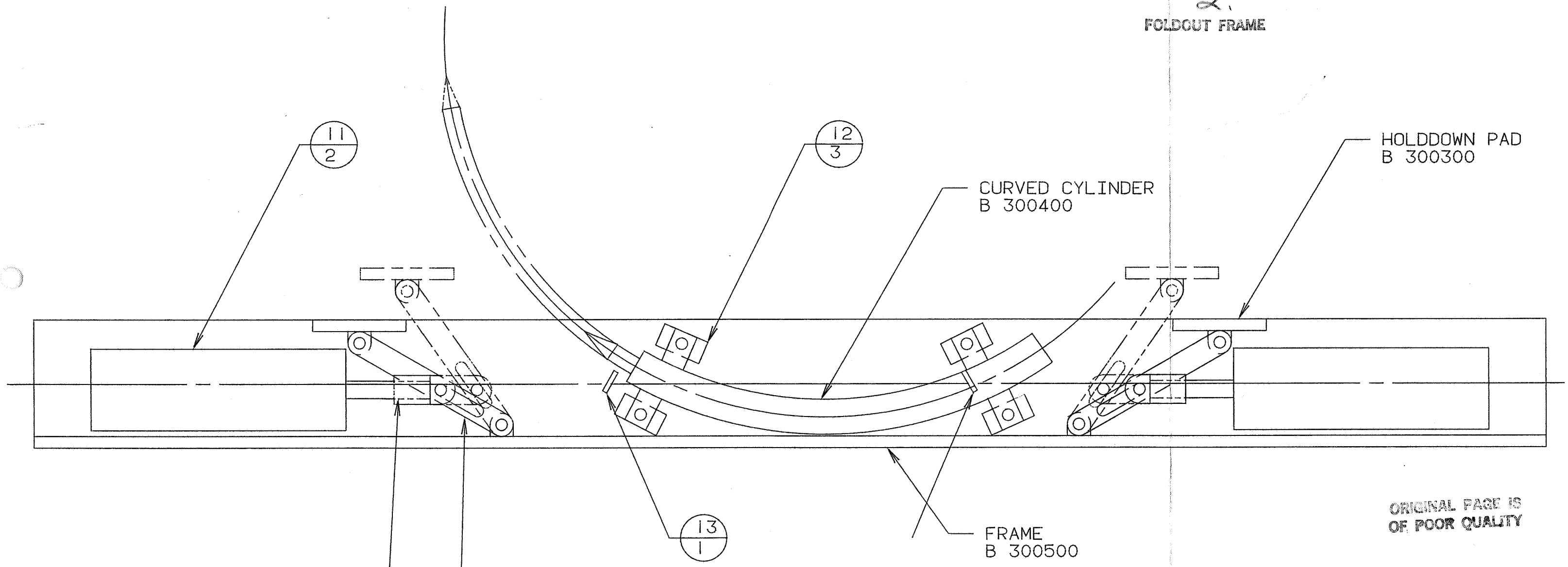
APPENDIX I.

ITEM	QUANT	DESCRIPTION
1	4	LOAD CELL
2	1	OPTICAL POSITION SENCOR
3	2	3" BORE, 5"STROKE CYLINDERS

1.
FOLDOUT FRAME

2.
FOLDOUT FRAME



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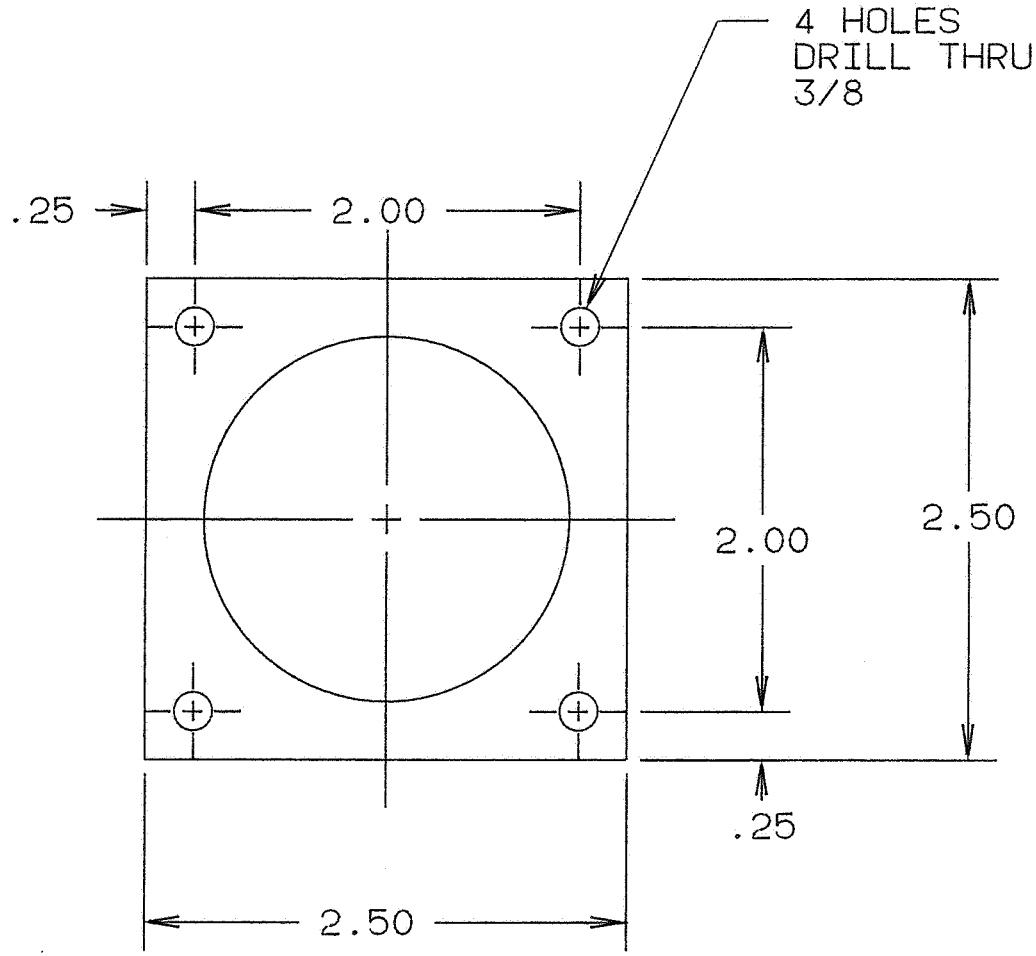
PLANE VIEW



SIDE VIEW

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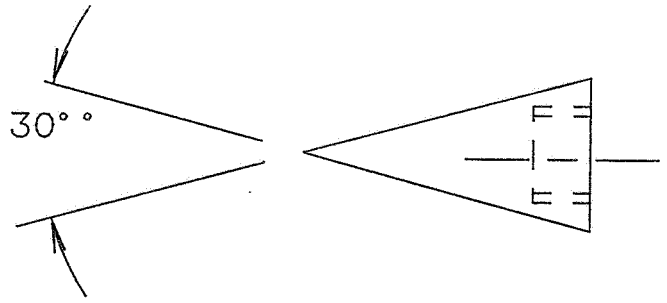

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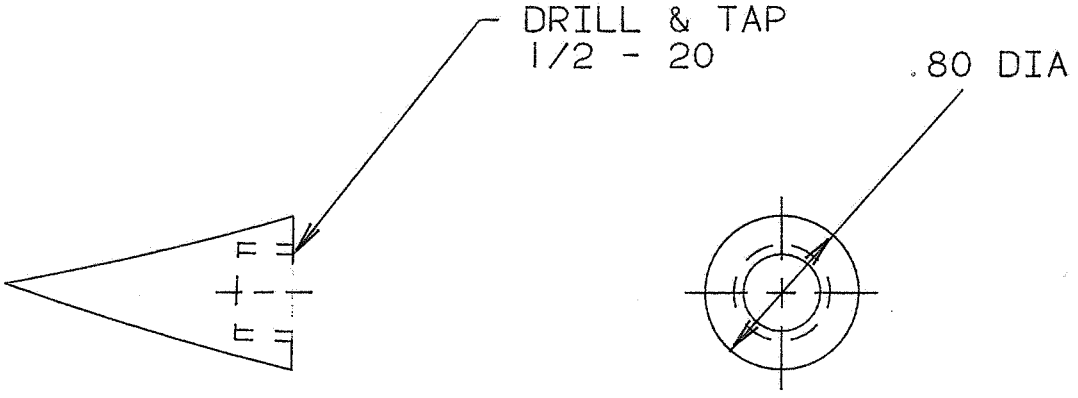

PLANE VIEW

SIDE VIEW

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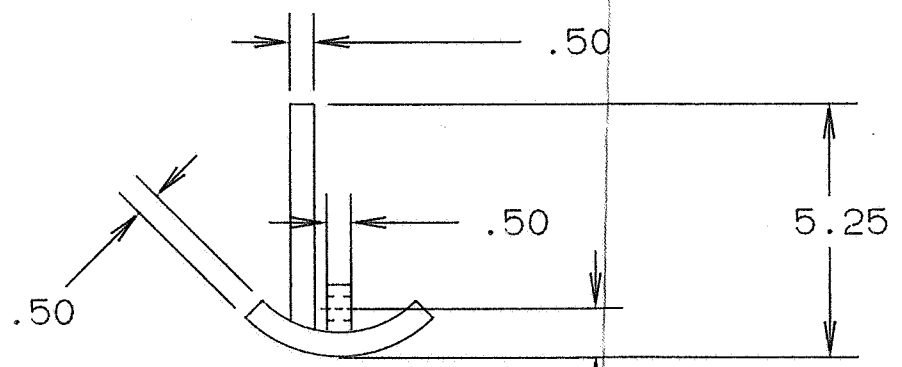

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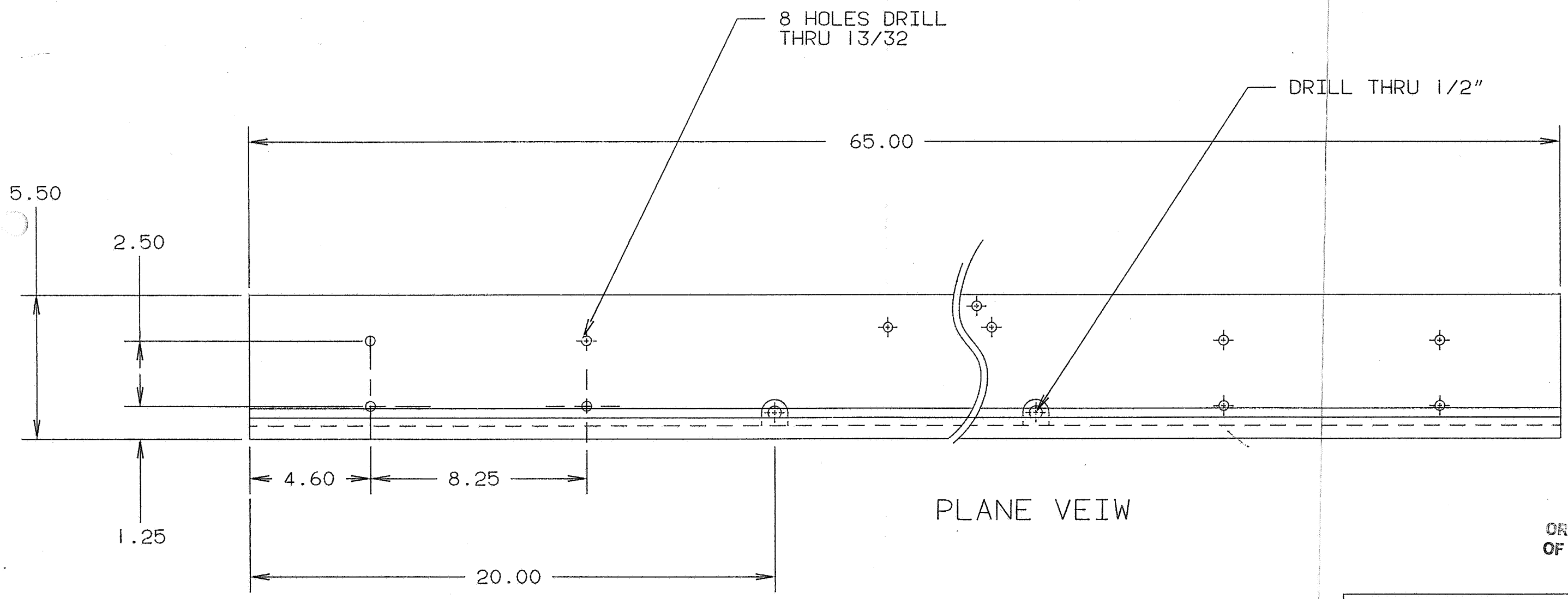

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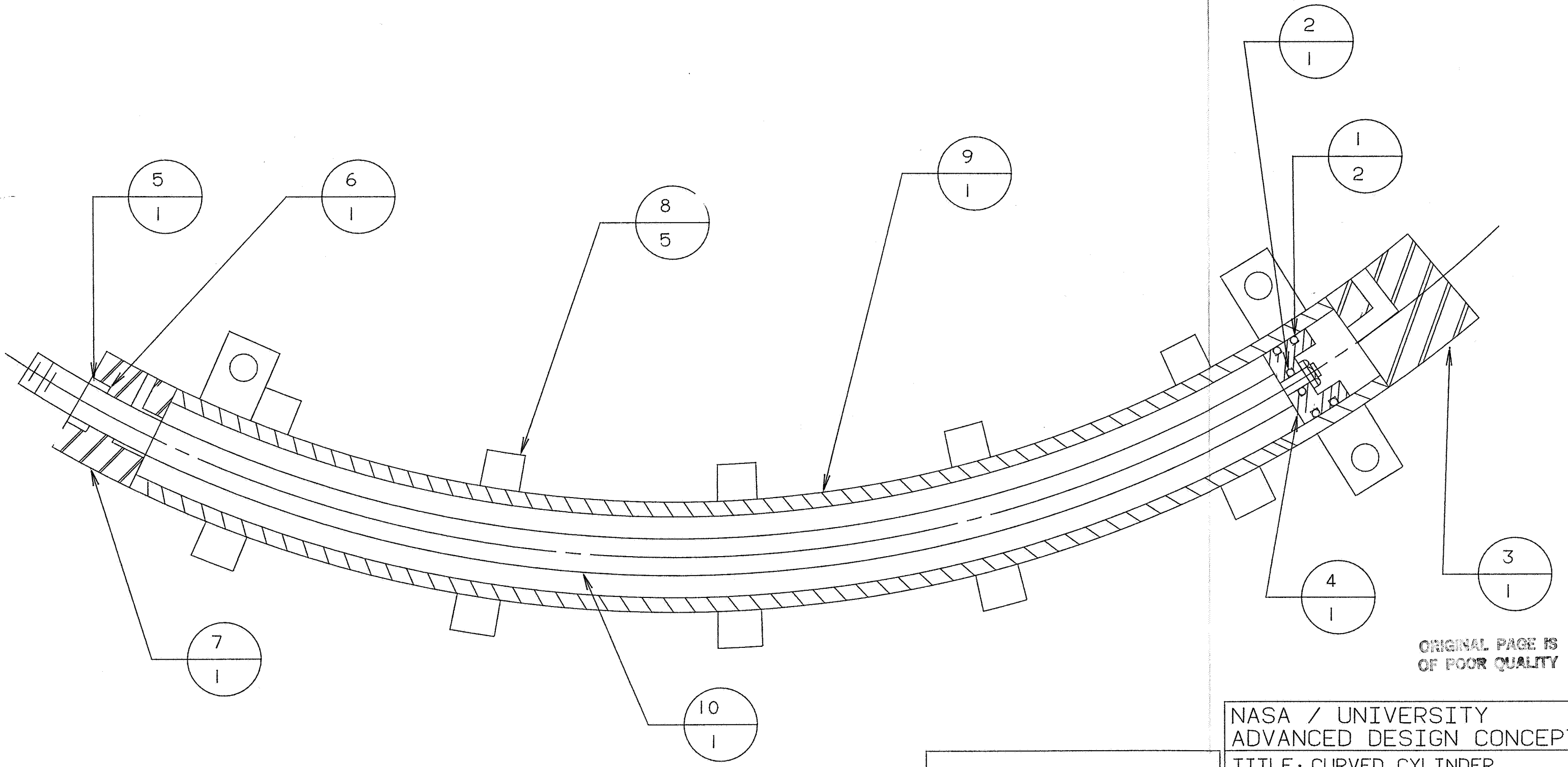

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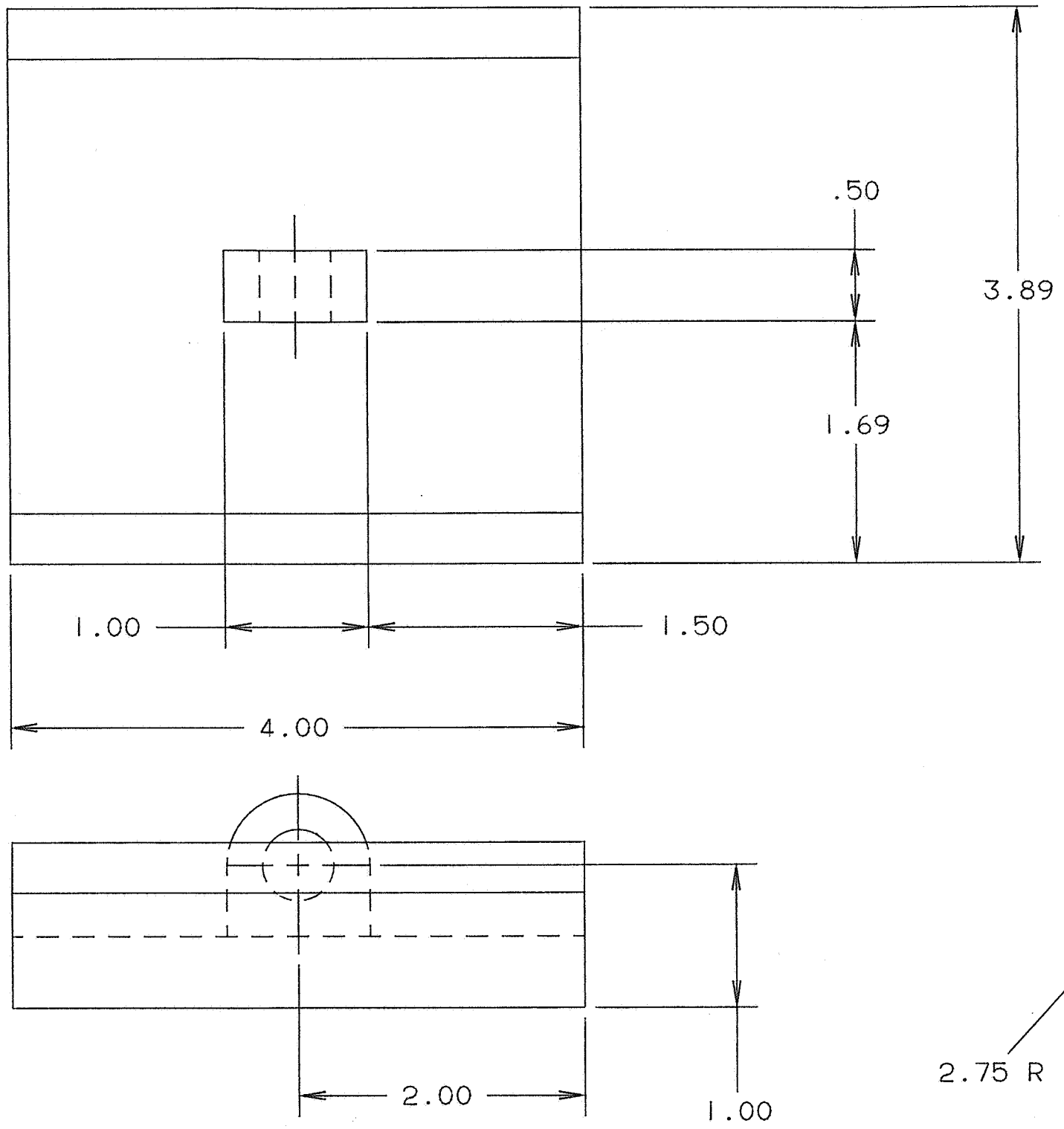

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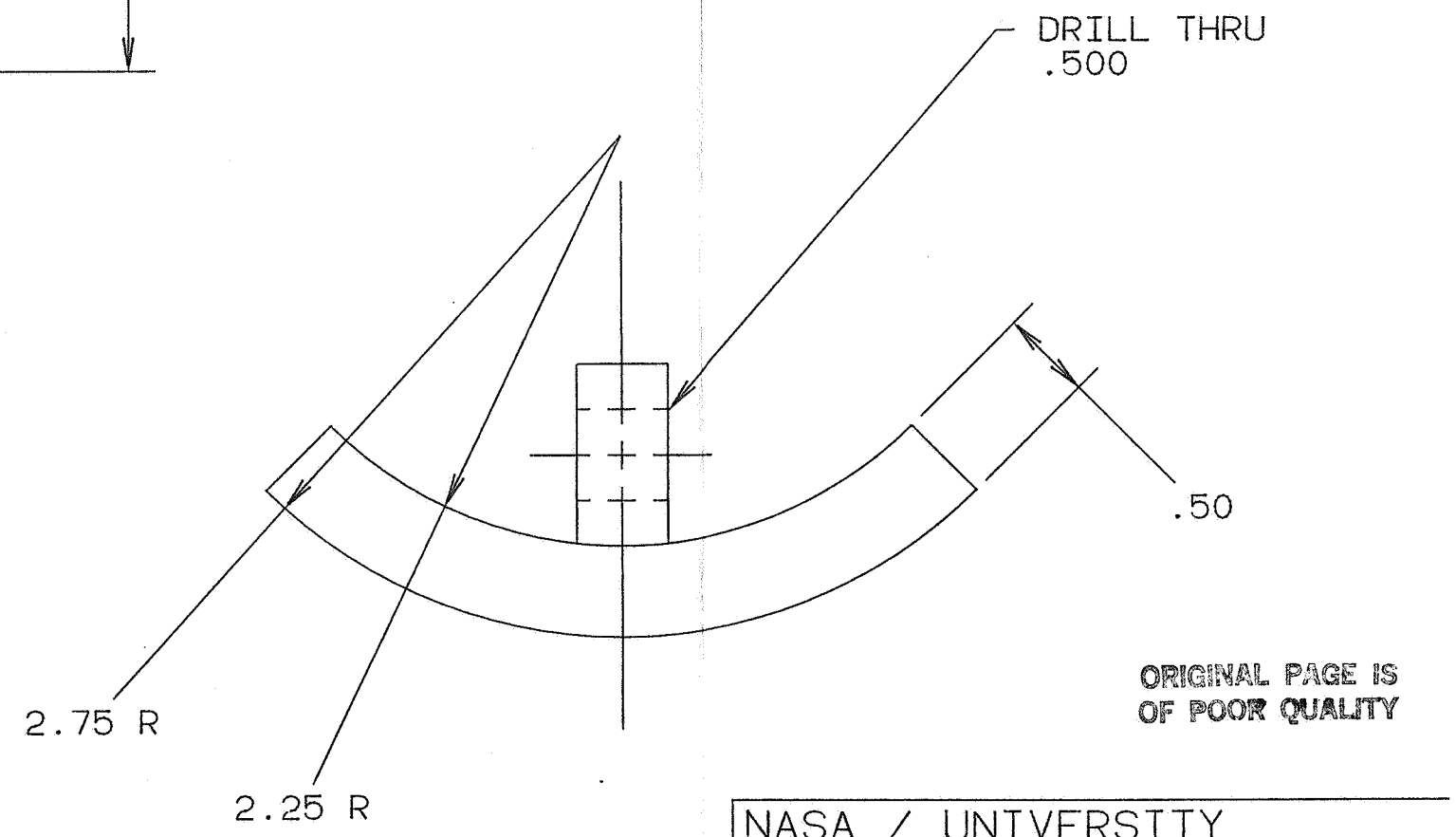

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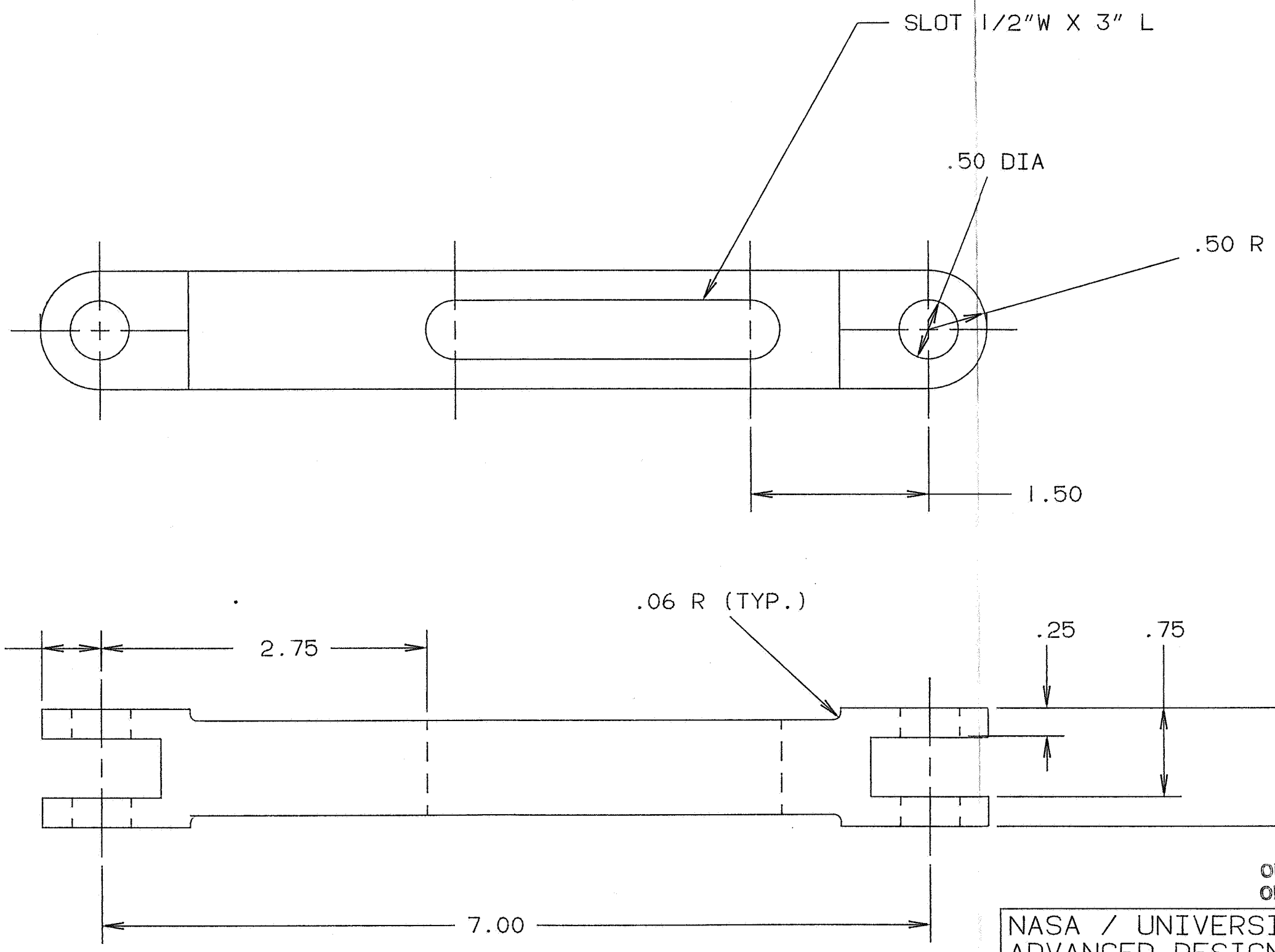

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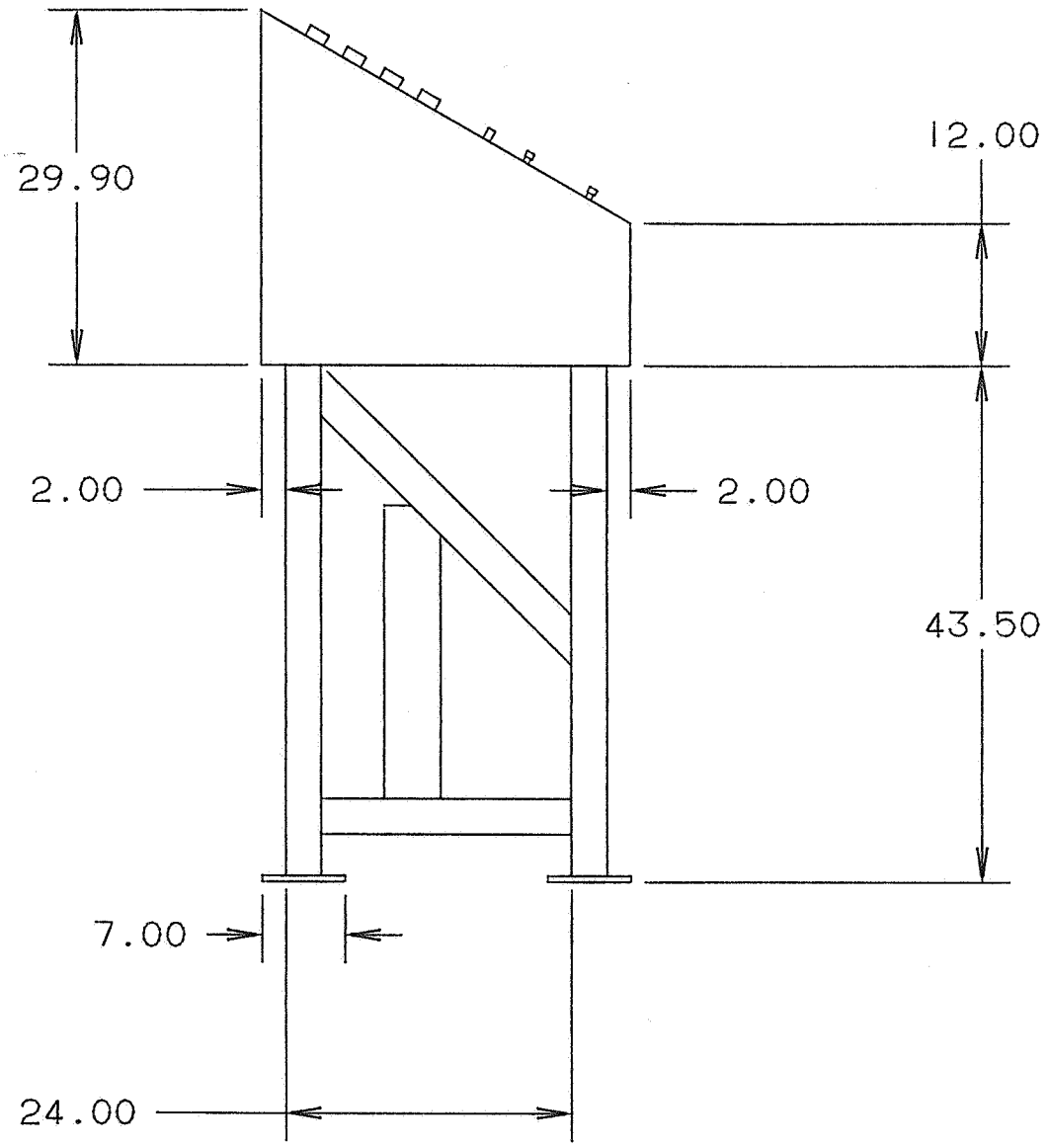

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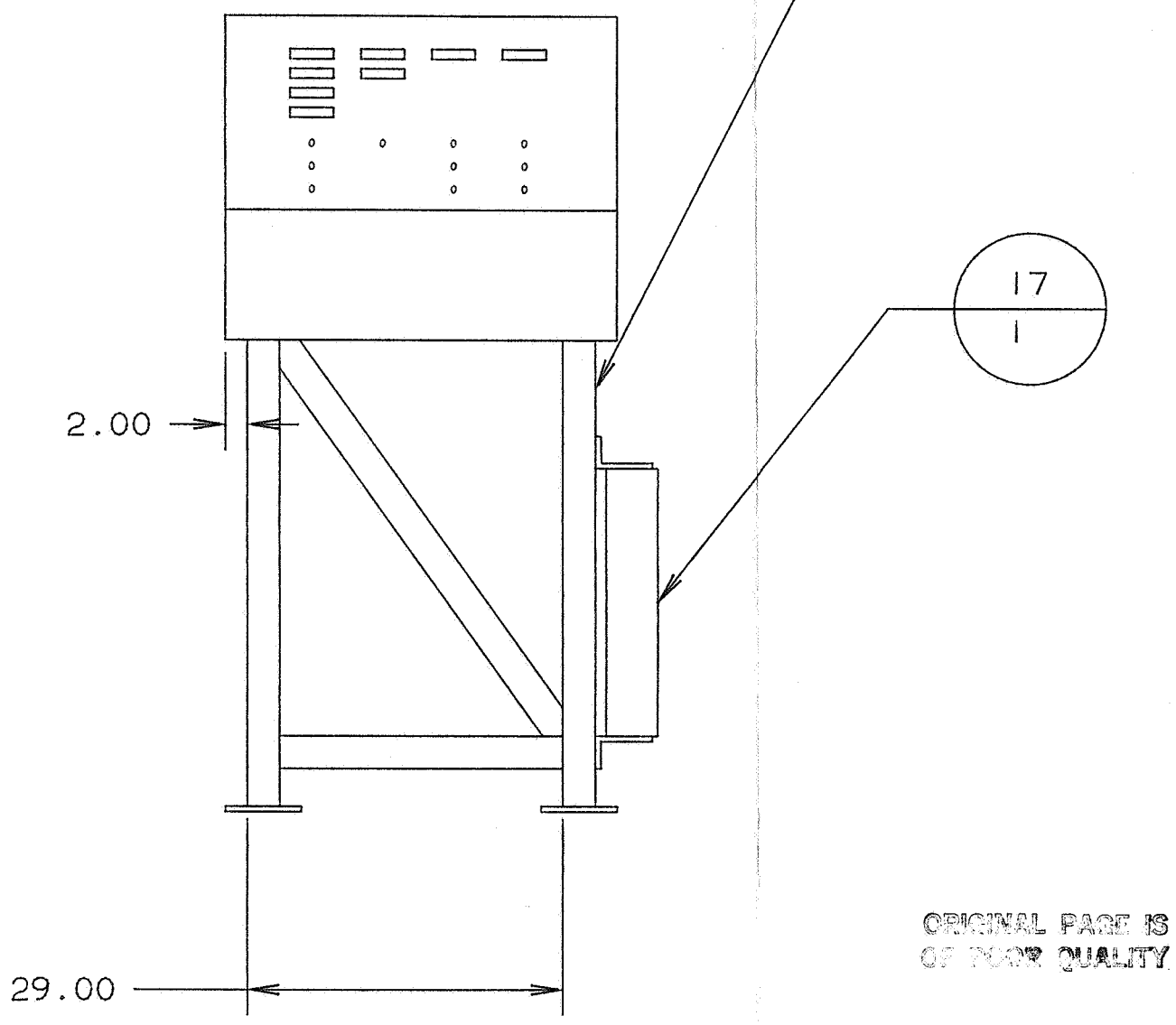

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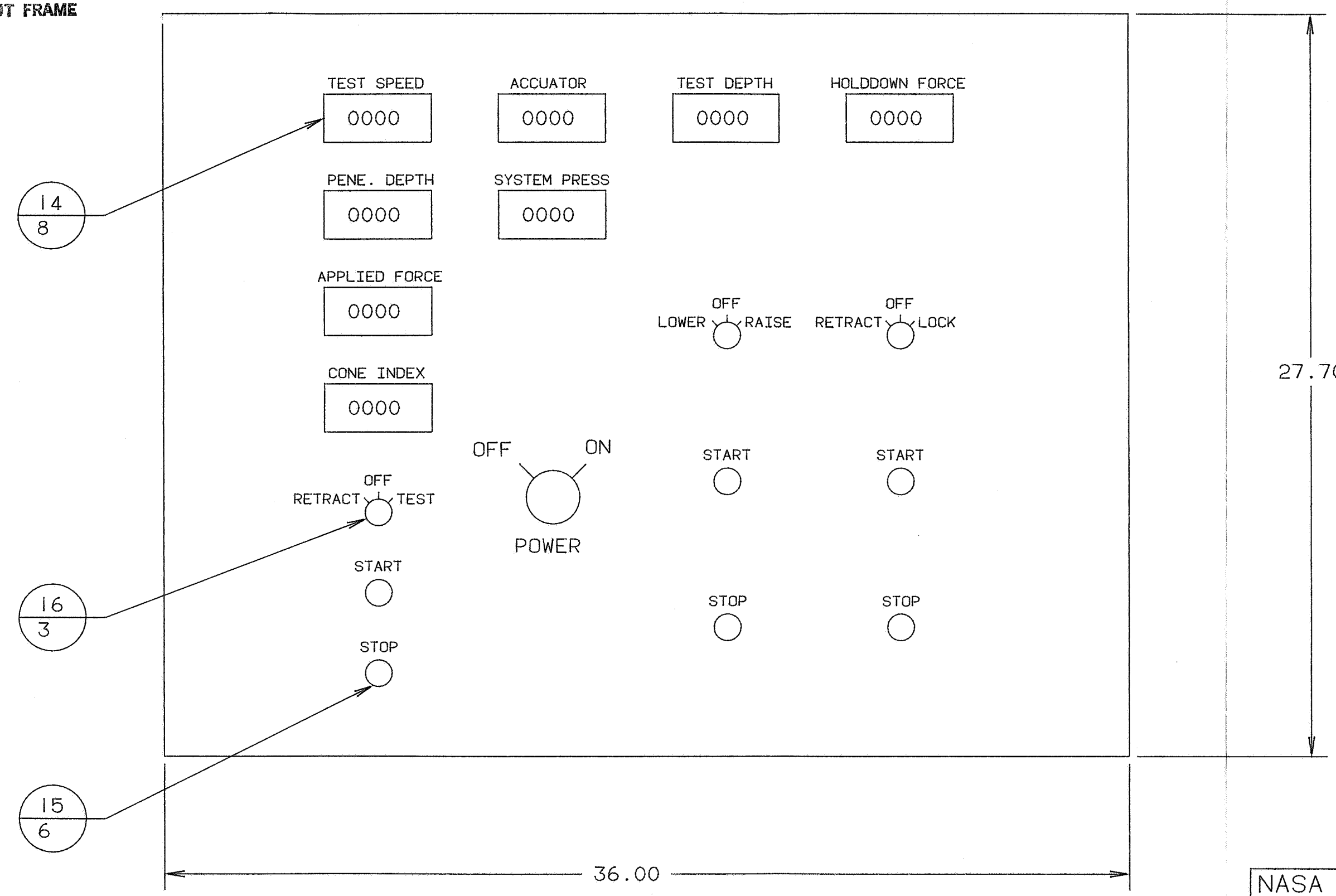

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APPENDIX II.

PARTS LIST

PROJECT : LUNAR CONE PENETROMETER

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	ITEM	QUANT	DESCRIPTION
	1	2	BLOCK VEE PACKING FOR MS90085
			CYLINDER, 1 1/2" BORE, HUNT VALUE CO
	2	1	"O" RING, PISTON SEAL FOR MS290085
			CYLINDER, 1 1/2" BORE, HUNT VALUE CO.
	3	1	CYLINDER COVER, BLIND END FOR
			MS290085 CYLINDER, 1 1/2" BORE
			HUNT VALUE CO.
	4	1	PISTON FOR MS290085 CYLINDER,
			1 1/2" BORE, HUNT VALUE CO.
	5	1	ROD WIPER FOR MS200985 CYLINDER,
			1 1/2" BORE, HUNT VALUE CO.
	6	1	PISTON ROD PACKING FOR MS290085
			CYLINDER, 1 1/2" BORE, HUNT VALUE CO.
	7	1	BEARING RETAINER FOR MS290085
			CYLINDER, 1 1/2" BORE, HUNT VALUE CO.

PARTS LIST

PROJECT : LUNAR CONE PENETROMETER

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	ITEM	QUANT	DESCRIPTION
	8	5	BOLT GUIDES DRWING. #B 300100
	9	1	CYLINDER TUBE, 16.25 IN CENTERLINE
			RADIUS, .15" WALL THICKNESS
	10	1	SHAFT, 16.25" CENTERLINE RADIUS
			.75" DIAMETER
	11	2	3" BORE, 5" STROKE, 200PSI,
			CYLINDER, #MS490085, HUNT VALUE CO
	12	3	LOAD CELLS, TENSION AND COMPRESSION
	13	1	OPTICAL ENCODER
	14	8	PANEL VOLTMETERS, NLS#RM-452,
			CASE TYPE C, RANGE 1000
	15	6	PUSH BUTTONS SWITCH, ARROW HART
			#83094C, WITH SNAP ON BUTTON CAP
	16	4	THREE POSITION ROTARY SWITCH

APPENDIX III.

RECORD OF INVENTION - Part I

This is an important legal document. Read instructions carefully before filling in data.

PROJECT NO. _____

CONTRACT NO. _____ RECOMMENDED SECURITY CLASSIFICATION _____ REC. OF INV. NO. _____

1. NAME OF INVENTOR: DAVID ERIC MORLAN — POSITION: STUDENT

2. DEPARTMENT OR DIVISION: N/A

3. DATES OF EMPLOYMENT: N/A

4. PRESENT ADDRESS (No. Street, City, County, State): GA. TECH Bx 33811, ATLANTA GA — TELEPHONE: (404) 875-0192 — PERMANENT OR UNTIL: 6/15/85

5. PERMANENT ADDRESS (No. Street, City, County, State): 6 TIMBERLINE DR. BRIDGEWATER NJ — TELEPHONE: (201)-526-0976

6. NAMES (S) AND ADDRESS (ES) OF CO-INVENTORS (If any): N/A

7. DESCRIPTIVE TITLE OF INVENTION: A CONE PENETROMETER USED TO DERIVE A SUBSURFACE PROFILE OF SOILS.

8. LIST DRAWINGS, SKETCHES, PHOTOS, REPORTS, DESCRIPTIONS, NOTEBOOK ENTRIES, ETC. WHICH SHOW OR DESCRIBE INVENTION

9. EARLIEST DATA AND PLACE INVENTION WAS CONCEIVED (Brief outline of circumstances): 4/19/85 - DEVICE WAS CONCEIVED AS A SENIOR PROJECT (COURSE # ME 4182) AT THE GA. INSTITUTE OF TECHNOLOGY.

10. DATE AND PLACE OF FIRST SKETCH, DRAWING OR PHOTO: 4/20/85 - GA. TECH

11. DATE AND PLACE OF FIRST WRITTEN DESCRIPTION: 5/20/85 - GA. TECH

12. **DISCLOSURE OF INVENTION TO OTHERS**

NAME, TITLE AND ADDRESS	FORM OF DISCLOSURE	DATE AND PLACE OF DISCLOSURE	WAS SIGNATURE OBTAINED (YES OR NO)

12.A IMPORTANT - HAVE ANY PUBLICATIONS OR REPORTS BEEN MADE ON THIS INVENTION? No

13. DATE AND PLACE OF COMPLETION OF FIRST OPERATING MODEL OR FULL SIZE DEVICE: NONE

14. PRESENT LOCATION OF MODEL: NONE

15. DATE, PLACE, DESCRIPTION AND RESULTS OF FIRST TEST OR OPERATION: NONE

16. NAMES AND ADDRESSES OF WITNESSES OF FIRST TEST

NONE

17. DATE, PLACE, DESCRIPTION AND RESULTS OF LATER TESTS (name witnesses)

NONE

18. IDENTIFY RECORDS OF TESTS AND GIVE PRESENT LOCATION OF RECORDS

NONE

19. PRIOR REPORTS OR RECORDS OF INVENTION TO WHICH INVENTION IS RELATED

NONE

20. OTHER KNOWN CLOSELY RELATED PATENTS, PATENT APPLICATIONS AND PUBLICATIONS

PATENT OR APPLICATION NO.	DATE	TITLE OF INVENTION OR PUBLISHED ARTICLE	NAME OF PUBLICATION
NONE			

21. EXTENT OF USE: PAST, PRESENT AND CONTEMPLATED (Give dates, places and other pertinent details)

NONE

22. DETAILS OF INVENTION HAVE BEEN RELEASED TO THE FOLLOWING COMPANIES OR ACTIVITIES

NAME AND ADDRESS	INDIVIDUAL OR REPRESENTATIVE	CONTRACT NO.	DATE
NASA			

SIGNATURE OF INVENTOR D Morlan DATE 5/26/05

RECORD OF INVENTION - Part II

(Attach to Record of Invention Part I)

REC. OF
INV. NO. _____

This Disclosure of Invention should be written up in the inventor's own words and generally should follow the outline given below. Sketches, prints, photos and other illustrations as well as reports of any nature in which the invention is referred to, if available, should form a part of this disclosure and reference can be made thereto in the description of construction and operation.

1. INVENTORS NAME(S)
DAVID MORLAN

2. TITLE OF INVENTION
CONE PENETROMETER FOR LUNAR SUBSURFACE SOIL

For answers to following questions use remainder of sheet and attach extra sheets if necessary.

3. GENERAL PURPOSE OF INVENTION. STATE IN GENERAL TERMS THE OBJECTS OF THE INVENTION.

4. DESCRIBE OLD METHOD(S) IF ANY, OF PERFORMING THE FUNCTION OF THE INVENTION.

5. INDICATE THE DISADVANTAGES OF THE OLD MEANS OR DEVICE(S).

6. DESCRIBE THE CONSTRUCTION OF YOUR INVENTION, SHOWING THE CHANGES, ADDITIONS AND IMPROVEMENTS OVER THE OLD MEANS OR DEVICES

7. GIVE DETAILS OF THE OPERATION IF NOT ALREADY DESCRIBED UNDER 6.

8. STATE THE ADVANTAGES OF YOUR INVENTION OVER WHAT HAS BEEN DONE BEFORE.

9. INDICATE ANY ALTERNATE METHODS OF CONSTRUCTION.

10. IF A JOINT INVENTION, INDICATE WHAT CONTRIBUTION WAS MADE BY EACH INVENTOR.

11. FEATURES WHICH ARE BELIEVED TO BE NEW.

12. AFTER THE DISCLOSURE IS PREPARED, IT SHOULD BE SIGNED BY THE INVENTOR(S), AND THEN READ AND SIGNED AT THE BOTTOM OF EACH PAGE BY TWO WITNESSES USING THE FOLLOWING STATEMENT:
"DISCLOSED TO AND UNDERSTOOD BY ME THIS_____DAY OF_____19___
SIGNATURE_____."

SEE ATTACHED REPORT.

REC. OF
INV. NO. _____

_____
INVENTOR

_____ 19____

DISCLOSED TO AND UNDERSTOOD BY ME

ON THIS_____ DAY OF_____ 19____

_____
WITNESS

DISCLOSED TO AND UNDERSTOOD BY ME

ON THIS_____DAY OF_____ 19____

_____
WITNESS